Polymer Charging with Regolith Simulant Particles at Martian Environmental Conditions IESJ Annual Meeting

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Abstract-Andesite particles from Hawaiian volcanic ash which simulate the Martian regolith were rolled over five polymers under simulated Martian environmental conditions to study the electrostatic response of these polymers to granular material that may be encountered during a Mars landing mission. A mission-ready flight instrument consisting of five electrometer sensors, capped with the five polymers, was used to measure the electrostatic charge generated on the polymers as the simulant particles were rolled back and forth along their surfaces. The martian atmospheric environment at the surface of the planet was partially simulated in a vacuum chamber using CO_2 at 9 mbar and room temperature. The weight of the simulant particles on the polymer surfaces generated charges of the order of 20 pC on the 6 mm-diameter polymer surfaces.

I. INTRODUCTION

NASA's Viking and Pathfinder landing missions to Mars showed that large areas of the planet's surface are covered by a thin blanket of granular material [1]. Rover wheels rolling on the planet surface, as well as the space boots and suits of future astronauts on a manned mission, will be in close contact with these fine soil materials, possibly generating electrostatic charges. Electrostatic attractions between this possibly charged granular material and the surfaces that it may come into contact would keep these particles attached to those surfaces with undesirable results. Moreover, electrostatic potential differences of several hundred volts might be generated when the contact forces are large, endangering equipment and even the safety of future astronauts [2-5]. Clearly, mitigation of this problem is of great interest to NASA.

Prior to this work, no direct experiment to determine the electrostatic properties of martian soil material has been conducted. Indirect experiments have shown that dust can be electrostatically attracted to surfaces on Mars [2,6]. Several ground tests in simulated martian environment have been performed to study the electrostatic charge generated on surfaces [2,7]. In the work reported here, the charge generated on insulator surfaces by light contact with soil simulant particles is measured at partially simulated martian environmental conditions.

II. EXPERIMENTS

A. Martian Soil Simulant

JSC Mars-1 soil simulant was used in these experiments [8]. This simulant, developed at NASA Johnson Space Center is the 1 mm and smaller fraction of altered volcanic ash from Hawaiian cinder cone. This simulant approximates the reflectance spectrum, mineralogy, chemical composition, grain size, density, porosity, and magnetic properties of the Martian soil as measured by instrumentation on the Viking and Pathfinder landers. A comparison of the chemical composition of the simulant with Martian soil is shown in Table 1.

Table 1. JSC Mars-1 Chemical Composition (Wt%)

Oxide	Viking 1	Pathfinder	JSC Mars-1	
			Fine	Coarse
SiO_2	43	44.0	40.2	39.3
Al_2O_3	7.3	7.5	25.1	26.2
TiO_2	0.66	1.1	3.53	3.42
Fe_2O_3	18.5	16.5	12.4	15.6
MnO	NA	NA	0.65	0.49
CaO	5.9	5.6	4.08	3.51
MgO	6	7.0	1.14	0.97
K_2O	<0.15	0.3	NA	NA
Na_2O	NA	2.1	1.79	0.91
P_2O_5	NA	NA	1.13	1.91
SO_3	6.6	4.9	0.86	0.29
Cl	0.7	0.5	NA	NA
LOI*	NA	NA	21.8 [8]	

*LOI: Loss on ignition. Weight loss after 2 hrs at 900°C; includes H_2O and SO_2

Figure 1. Multisensor electrometer with 5 insulators.

B. *The MECA Electrometer*

The Mars Environmental Compatibility Assessment (MECA) electrometer, a laboratory version of a flight instrument designed for a Mars landing mission, was used in these experiments. The MECA electrometer contains 5 triboelectric sensors each capped with insulators. The insulators are Fiberglass/epoxy G-10, Lexan? , Teflon, Rulon J? , and Lucite. The insulators have a diameter of 6.35 mm and a thickness of 2.01 mm and are mounted to a titanium housing in a row configuration (Fig. 1). The basic electronics is shown in Fig 2.

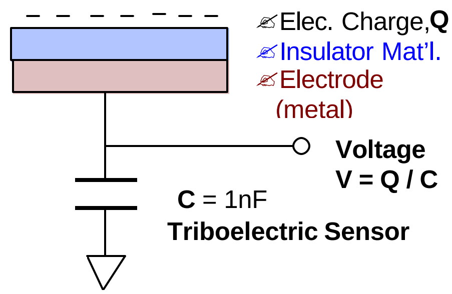


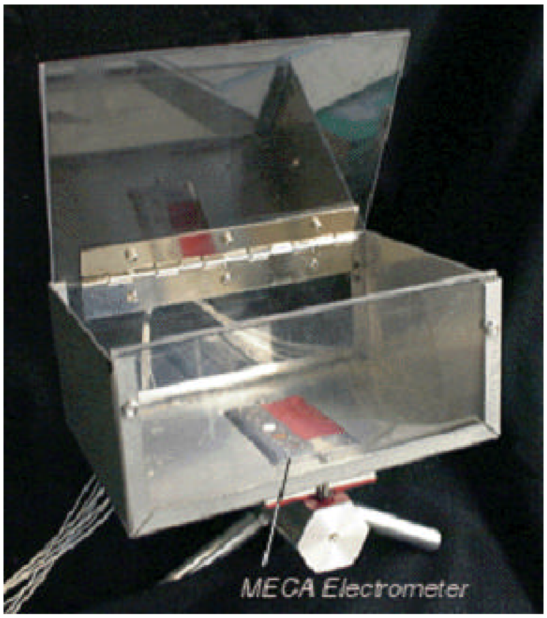
Figure 2. Charge to voltage converter. The circuit gain is 0.25 nC per volt.

C. *Rocking Chamber*

The MECA electrometer was mounted at the bottom of a rocking chamber, a grounded metal container that rotates about a pivot point. (Fig. 3). The five polymer samples that cap the triboelectric sensors of the MECA electrometer are exposed to JSC Mars-1 simulant particles placed in the chamber. As the chamber rotates, simulant particles slide back and forth over the five samples. The polymer samples are actually positioned along a line perpendicular to the motion of the simulant particles to avoid cross talk. The entire assembly is placed in a vacuum chamber and a rotary motion feedthrough is connected to provide the rocking motion. The atmospheric composition of the vacuum chamber is primarily CO_2.

III. RESULTS

Figure 4 shows data obtained with Martian simulant soils. The container is initially rocked so that the simulant particles make frictional contact with each of the five triboelectric sensors. Immediately after this contact, a rapid decay is observed. Not much change in the response is observed after that, indicating a very slow charge decay rate. Eleven runs at pressures ranging from 10 to 130 mb and at <5% relative humidity were obtained. The results shown in Fig. 4 are typical. Figure 4 shows that Lexan developed a charge 20 pC followed by Fiberglass which charged to 16 pC, Lexan with 13 pC, and Rulon J and Teflon developing no charge. The voltage offset for each insulator's electrometer circuit was about 32 mV, as seen in Fig 4.



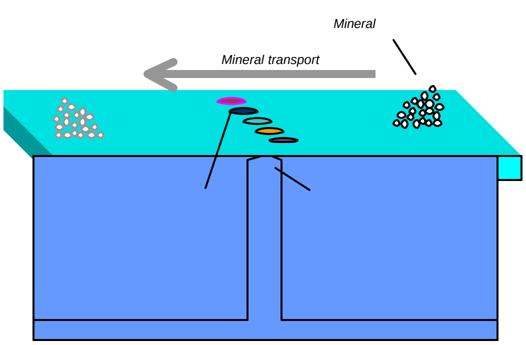


Figure 3. Diagram of the rocking chamber.

Minerals were also allowed to slide back and forth, in a repeated rocking motion after a small time delay. Fig. 5 shows typical results for this case. Sliding contact of the minerals with the five electrometer insulators starts at 20, 35, 70, 110, 180 seconds. The order in which the polymers charge is very similar to that of the single rocking motion shown in Fig. 4. In the repeated rocking case, the ordering from positive to negative is: Lucite, Lexan, Fiberglass, Teflon, and Rulon J.

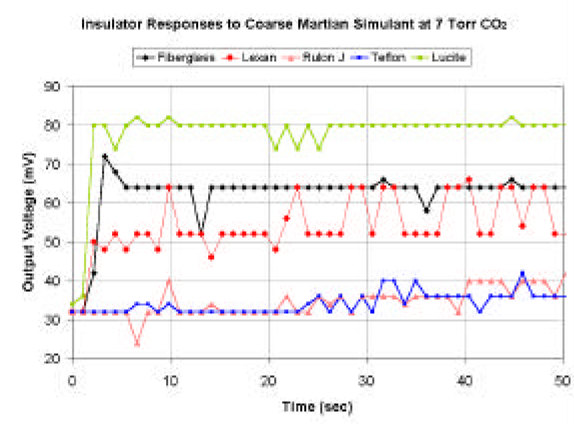


Figure 4. Charging of the five insulators in the MECA electrometer with the JSC Mars-1 Simulant.

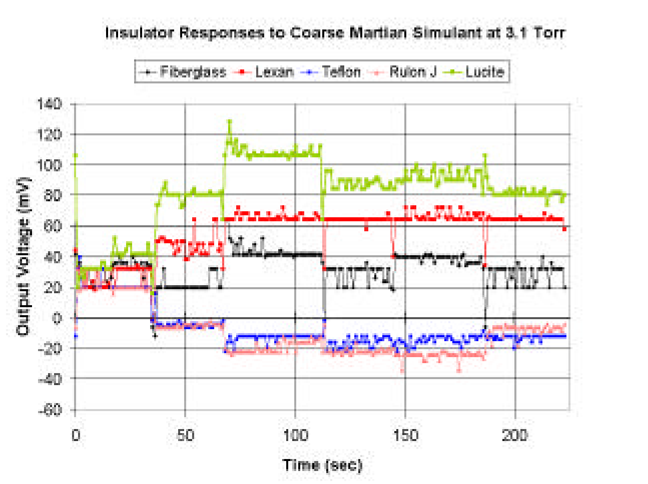


Figure 5. Charging of the five MECA electrometer insulators with repeated rocking motion.

IV. DISCUSSION

The data presented in Figures 4 and 5 demonstrate that the combined weight of Martian soil simulant particles of diameter <5? m is sufficient to produce triboelectric charging on insulator surfaces when the particles move in frictional contact over each surface. Lucite, Fiberglass and Lexan are observed to charge positively when the simulant particles slide over their surfaces with Lucite attaining the greatest amount of charging. Teflon and Rulon J, by contrast, exhibited negative charging. Figure 5 shows that the ordering of the five types of insulators by amount of charging is maintained through repeated exposure to the back and forth flow of simulant particles. This ordering matches most triboelectric series [9].

The sliding contact of the simulant particles with the polymer surfaces is a complex phenomenon. The diameters of the particles vary from a few microns to slightly less that one millimeter. Particles acquire charge due to interactions with other particles as well as when sliding along the grounded metal rocking chamber. It is then safe to assume that these particles possess charges of different magnitudes before making contact with the polymer.

The complexity of this interaction can be seen in Figure 5. Initial contact generates a certain charge which rapidly decays to a stable value as additional particles slide across the insulator. The small potentials generated by this contact are much lower than Paschen values for the low atmospheric pressures. At the very low humidities of these experiments, the polymers retain the charge for a long time. Subsequent sliding contacts usually generate additional charge. Since the particles themselves possess charges of different magnitudes, these contacts may neutralize part of the charge previously acquired by the insulators.

V. CONCLUSIONS

The aim of these experiments was not to understand this complex multiparticle-polymer electrostatic interaction but to simulate the movement of soil particles on Mars during wind storms. The real situation is equally complex, as particles pushed by the wind roll over other particles, over rocks, and undergo saltation. In all these cases, charge exchange takes place so that the particles making sliding contact with solar panels or equipment surfaces would already have charge.

Current experiments in our laboratory are attempting to more closely simulate the action of the wind in transporting particles above the surface. Experiments to measure the decay rates and the relative permittivities of these particles are also under way.

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References

1) A. Banin, B.C. Clark, and H. Wänke, "Surface Chemistry and Mineralogy", *Mars*, H.H Kieffer *et al*, Eds., University of Arizona Press, pp.594-625 (1992)

2) D.C. Ferguson, J.C. Kolecki, M.W. Siebert and D.M. Wilt, "Evidence for Martian Electrostatic Charging and Abrasive Wheel Wear from the Wheel Abrasion Experiment on the Pathfinder Sojourner Rover", *JGR*, **104**, 8747 (1999)

3) D.D. Sentman, "Electrostatic Fields in a Dusty Martian Environment," *Sand and Dust on Mars*, NASA CP-10074, p. 53 (1991)

4) J.G. Mantovani, C.I. Calle, E.E. Groop, and M.G. Buehler, "Triboelectric Charging of an Insulator's Surface Using Martian Soil Simulant," *Bulletin of the American Physical Society*, **45**, 26 (2000)

5) J.G. Mantovani, C.I. Calle, E.E. Groop, and M.G. Buehler, "Neutralizing Triboelectrically Generated Charge on Insulators under Martian-like Atmospheric Conditions," *Bulletin of the American Astronomical Society*, **32**, 1640 (2000)

6) Landis, G.A. (1996) "Dust Obscuration of Mars Solar Arrays" Acta Astronautica, Vol. 38, No. 11, pp. 885-891

7) C.I. Calle, J.G. Mantovani, C.R. Buhler, M.D. Hogue, A.W. Nowicki, and E.E. Groop, "Electrostatic Charging of Polymers by Particle Impact at Low Pressures", *Proc. The 4th Int Conf.. Appl. Electrostatics*, (in press).

8) C.C. Allen, K.M. Jager, R.V. Morris, D.L. Lindstrom, M.M. Lindstrom, and J.P. Lockwood, "JSC Mars-1: A Martian Soil Simulant", *Proc. Space 98*, pp. 469-476 (1998).

9) Henniker, J. (1962) Nature 196, p. 474.